

NIST-GCR-94-639

---

# DEVELOPMENT OF THE FIRE DATA MANAGEMENT SYSTEM

---

Frederick W. Mowrer  
Department of Fire Protection Engineering  
University of Maryland  
College Park, MD 20742

Issued June 1994  
August 1993



Sponsored by:  
**U.S. Department of Commerce**  
Ronald H. Brown, *Secretary*  
**Technology Administration**  
Mary L. Good, *Under Secretary for Technology*  
National Institute of Standards and Technology  
Arati Prabhakar, *Director*

### Notice

This report was prepared for the Building and Fire Research Laboratory of the National Institute of Standards and Technology under grant number 60NANB1D1164. The statements and conclusions contained in this report are those of the authors and do not necessarily reflect the views of the National Institute of Standards and Technology or the Building and Fire Research Laboratory.

# **Development of the Fire Data Management System**

## **Final Report**

**Grant No.: NIST 60NANB1D1164**

**Frederick W. Mowrer  
Department of Fire Protection Engineering  
University of Maryland  
College Park, MD 20742**

**August, 1993**

## Table of Contents

Abstract	iii
List of Figures	iv
Acknowledgements	v
1. Introduction	1
2. Recovery of Existing Data	1
3. Generation of Additional Data	3
4. Development of Engineering Guidelines for Use of FDMS	3
4.1 Engineering calculation methods for fire hazard analysis	4
4.2 Morphological charts of combustible elements in buildings	9
5. Summary and Concluding Remarks	24
6. References	25

## **Abstract**

The Fire Data Management System (FDMS) is being developed under international collaboration to provide uniform means for storing fire test data. The purpose of the present work has been to aid the development of the FDMS for practical use by fire safety design professionals with respect to the following three tasks:

- Recovery of existing data at BFRL/NIST for implementation into the FDMS.
- Generation of additional data not already available.
- Development of engineering guidelines for use of the FDMS.

To be of practical use by fire safety design professionals, the FDMS must contain relevant data and these data must be readily accessible. Currently, the data fields in the FDMS are too general and too restricted to be of practical design use. Additional data fields are needed in the FDMS to assist the design professional find flammability test data relevant to the design of different combustible objects in buildings. To help identify the types of additional data fields that are needed, a series of morphological charts have been developed to describe the types, elements and attributes of combustible objects in buildings. These morphological charts represent a first effort to describe a common syntax for identifying appropriate objects and their attributes for flammability analyses. Further refinement of the morphological charts is needed.

## List of Figures

Figure 1. Morphological chart of the architectural features of a domestic window.	9
Figure 2. Morphological chart of the major object types for building fire hazard analysis.	10
Figure 3. Morphological chart for columns, beams and girders.	11
Figure 4. Morphological chart for floor/ceiling assemblies.	12
Figure 5. Morphological chart for roof/ceiling assemblies.	13
Figure 6. Morphological chart for interior partitions.	14
Figure 7. Morphological chart for exterior walls.	15
Figure 8. Morphological chart for windows.	16
Figure 9. Morphological chart for doors.	17
Figure 10. Morphological chart for seating furniture.	18
Figure 11. Morphological chart for beds.	19
Figure 12. Morphological chart for casework.	20
Figure 13. Morphological chart for artwork.	21
Figure 14. Morphological chart for window treatments.	22
Figure 15. Morphological chart for stored commodities.	23
Figure 16. Morphological chart of equipment and appliances.	24

## **Acknowledgements**

The assistance of Amy Cheng, Jeff Collins and Jay Torner, students in the Department of Fire Protection Engineering at the University of Maryland at College Park, is gratefully acknowledged.

## **1. INTRODUCTION**

Several fire research institutions have been cooperating to establish the Fire Data Management System (FDMS), a software system intended for use by fire safety design professionals. The FDMS is a software program currently in the program implementation stage, although some revisions to program concept continue. Ultimately, the goals of the FDMS are to provide for:

- An integrated data base of fire test data
- Uniform standards for exchange of fire test data
- Uniform and customized means of reporting material fire properties
- Automated fire test data input into fire models.

A large amount of fire test data, particularly data from the Cone Calorimeter, has been acquired at the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST) over the past decade. But relatively little of these data have been incorporated into the FDMS. At the same time, the data that have been acquired are not comprehensive. There are far more products and materials for which relevant fire test data do not exist than for which such data do exist. Fire safety professionals will need a comprehensive FDMS to consider the range of alternatives available for a particular application. Finally, fire safety professionals will require guidelines for use of the FDMS. Methods to consolidate and access relevant data efficiently and comprehensively are necessary for the effective use of the FDMS. This will require future expansion of the data structure of the FDMS.

The purpose of the present work has been to aid the development of the FDMS with respect to the following three tasks:

- Recovery of existing data at BFRL/NIST for implementation into the FDMS.
- Generation of additional data not already available.
- Development of engineering guidelines for use of the FDMS.

A two-year project was proposed to complete these tasks. Due to proposed changes in the formats of FDMS files (Poitier, 1993), only the first year of this grant was funded. The idea was to complete the project once the proposed FDMS format changes were established. Consequently, the first and last objectives have only been partially achieved and the second task has not been initiated. This final report documents the status of the project at the end of the first year's work.

## **2. RECOVERY OF EXISTING DATA**

The recovery of existing Cone Calorimeter data for implementation into the FDMS was initiated during the first year. These data have been stored on three computer systems at BFRL. These computer systems, listed chronologically in terms of the dates of tests, include:

- TECHTRAN system
- Concurrent (Perkins-Elmer) system
- Hewlett-Packard (HP) system

The recovery of existing Cone Calorimeter data was performed chronologically, with the oldest data files recovered first. This order was established for a number of reasons, the primary ones being:

- The concern that the older TECHTRAN system was more likely to fail first.
- The HP system was being used regularly for data acquisition and consequently was not available for data reduction.

The TECHTRAN system is an early 1980s vintage device that uses 8-inch floppy diskettes for data storage. Raw data from the earliest Cone Calorimeter tests were stored on these 8 inch diskettes. Data from tests up to test number T1568 were stored on this system. These raw data were transferred via a serial port connection to an IBM PC and are now stored on PC compatible diskettes. Not all data stored on the TECHTRAN system were recoverable. Some of the 8 inch diskettes could not be read. But the vast majority of the test data stored on the TECHTRAN has been transferred to the PC environment. These data are awaiting reduction and transfer into the FDMS.

Data from tests numbered T774 through T1499 were stored on the Concurrent (Perkins-Elmer) minicomputer system at BFRL. Note the overlap between data stored on the Concurrent system and on the TECHTRAN system. Much of the Cone Calorimeter data on the Concurrent system were stored in both raw and reduced formats. The reduced data format has been called "NBS(old2)."

The DCS program developed at the Norwegian Fire Research Laboratory (Lonvik and Opstad, 1991) can convert data files from the "NBS(old2)" format to an "export" format compatible with the FDMS. The DCS program is being used to convert reduced data files in the "NBS(old2)" format from the Concurrent system to the FDMS compatible "export" format.

Data for tests above approximately T1500 are stored on the HP computer system that until recently was being used for Cone Calorimeter data acquisition at BFRL. Because of this use, this system was not available for transferring data to an IBM PC and ultimately to the FDMS. The HP system is no longer used as the primary data acquisition system for the Cone Calorimeter. As this report was being prepared, preparations were being made to connect the HP system to an IBM PC so that the data stored on the HP system could be transferred.

Raw data is stored on the HP system in a format called "NBS(old1)." The DCS software is supposed to be able to convert data from the "NBS(old1)" format to the FDMS "export" format, but version 1.21 of DCS did not work correctly. DCS would simply read in the raw data and convert the raw data to the vector data of the "export" format without performing the appropriate data reduction. This should be corrected to permit the DCS software to be used to convert data from the "NBS(old1)" format to the FDMS "export" format.

### **3. GENERATION OF ADDITIONAL DATA**

The generation of additional data is a task that was intended to be undertaken in the second year of this project. The intention was to analyze the existing data to determine what additional data were needed to make the FDMS more comprehensive and consequently more useful to the practicing fire safety professional. This task was not accomplished due to termination of this project after the first year. Once the final format of the FDMS is established, this task should be reconsidered.

The need for additional data should be considered in the context of the morphology of combustible products. Many products are composite assemblies of multiple materials, some of which may be combustible and some noncombustible. In considering the need for additional data, it became apparent that this need could be considered in the context of morphological charts of combustible products. Such charts would enumerate the various possible combinations of materials that could be used in a product. In this context, the fire safety professional could consider the available data in the FDMS as well as the full range of alternatives available for a particular design.

Morphological charts could also be used to guide the future development of the user interface for the FDMS. Ultimately, a fire safety professional should be able to access and retrieve data from the FDMS based on the proposed use rather than on the basis of the materials tested. Such access will require additional data fields in the FDMS.

### **4. DEVELOPMENT OF ENGINEERING GUIDELINES FOR USE OF THE FDMS**

The third task of this project has been the development of engineering guidelines for use of the FDMS by practicing fire safety professionals. The goal of this task has been to develop methods to make the FDMS more accessible and more useful to practicing fire safety professionals. These guidelines fall into two general categories:

- Engineering calculation methods for fire hazard analysis using data stored in the FDMS
- Methods to make access to the data in the FDMS easier and more relevant to practical fire safety design issues.

The first topic has been the subject of considerable research, particularly for the past decade. Calculation methods ranging from very simple to very complex have been developed to permit the quantitative analysis and prediction of large scale fire performance based on fundamental and derived properties obtained in small scale quantitative fire tests. Some of the key concepts that have been developed are summarized in Section 4.1.

With respect to the second topic, it might be said that fire safety depends on the details. The flammability of a product may turn on seemingly minor differences in construction details. For

example, the apparent flammability of some wall lining materials is very sensitive to the type and quantity of adhesive used to mount the finish material (Belles, *et al.*, 1987) and on the substrate to which the finish is attached. The FDMS must be able to distinguish such details to be of practical use by fire safety professionals. Currently, accessing data in the FDMS for practical design purposes is difficult because the data format for the FDMS only permits a product to be identified in terms of two product ID fields.

The construction of morphological charts of combustibles in buildings may be a useful means to identify the types of data fields needed to distinguish products and test data for practical applications. A morphological chart is an exhaustive enumeration of the elements or attributes of an object. The construction of morphological charts of combustibles in buildings is discussed in more detail below in Section 4.2.

## **4.1 Engineering Calculation Methods for Fire Hazard Analysis**

Engineering calculations methods for fire hazard analysis fall into a number of broad categories, including, but not necessarily limited to:

- Ignition characteristics
- Heat release rate/fire growth rate calculations
- Flame spread calculations
- Fire consequence analysis

The first category addresses the potential for ignition under assumed fire exposure conditions. This category is related to the third category because flame spread can be considered as the sequence ignition of different sections of a combustible product. The second two categories are also related because the heat release rate history is a function of the flame spread rate. Furnishing fires are commonly considered in terms of heat release/fire growth rates, while finishes are commonly considered in terms of flame spread rates. Most current fire consequence analysis models, such as CFAST (Peacock, *et al.*, 1993) and Fire Simulator in FPETOOL (Nelson, 1990) require the user to specify a fire history as input data, then compute the consequences of this specified fire history in terms of thermal and nonthermal hazards in a space or building.

Engineering calculation methods related to these four categories have been documented extensively in the fire research literature. Many of these methods have been summarized in the *SFPE Handbook of Fire Protection Engineering* (DiNenno, 1988). Consequently, these methods are not described in detail here. A summary of some of the work of practical interest to fire safety professionals is included here.

### **4.1.1 Ignition characteristics**

The ignition characteristics of a material or product generally relate to the "ease of ignition" of the material or product. A thermal model of ignition is generally assumed, with a product tested at a constant exposure heat flux. Based on classical heat transfer theory, the product is assigned an

effective ignition temperature and effective thermal properties. The effective thermal properties are generally assumed to be constant and the product is assumed to be inert until ignition occurs.

Products are generally cast into two groups:

- Thermally thin
- Thermally thick

A heat balance on a thermally thin material exposed to an incident heat flux can be expressed as:

$$\dot{q}'' = \rho c \delta \frac{dT}{dt} \quad (1)$$

For a constant heat flux at the surface, the time to ignition of a thermally thin material can be expressed as:

$$t_{ig} = \rho c \delta \frac{(T_{ig} - T_o)}{\dot{q}''} \quad (2)$$

The time to ignition of a thermally thick material under the condition of a constant heat flux at the surface is:

$$t_{ig} = \frac{\pi k \rho c}{4} \left[ \frac{(T_{ig} - T_o)}{\dot{q}''} \right]^2 \quad (3)$$

For the case of a constant heat flux, the total energy absorbed by a thermally thick material up to the time of ignition can be calculated as:

$$q_{ig} = \dot{q}'' t_{ig} = \frac{\pi k \rho c}{4 \dot{q}''} [T_{ig} - T_o]^2 \quad (4)$$

This equation suggests that the energy absorbed by a thermally thick material up to ignition is not a constant value, but varies inversely with the incident heat flux. Some references cite fixed values for this parameter. Such references should be treated cautiously.

Babrauskas and Krasny (1985a) note that these theories for radiative ignition of solids are useful in suggesting the relative importance of material properties to the ignition characteristics of products, but are inadequate as numerical predictive tools. They cite the work of Hallman (1971), who studied the ignition characteristics of plastics and rubber and developed the following formula for the time to ignition:

$$t_{ig} = \frac{1035(T_{ig} - T_o)^{1.04} (k \rho c)^{3/4}}{(\alpha \dot{q}_i)^2} \quad (5)$$

According to Babrauskas and Krasny, this data correlation had uncertainties of about a factor of two.

This method of evaluating the ignition characteristics of materials is useful for comparing different products under similar exposure conditions and for estimating the relative effects the different parameters have on ignition characteristics. It may not answer the fundamental question of whether a product will ignite and propagate a flame when exposed to different realistic small ignition sources. Such realistic ignition sources may range from short term high intensity arcs and sparks, through matches and other small open flames, on up to larger open flames from wastebaskets or other small furnishings.

Babrauskas and Krasny (1985a) discuss issues related to the ignitability of upholstered furniture when exposed to small smoldering and flaming ignition sources. They also discuss results of mockup and full-scale tests using these ignition sources.

#### 4.1.2 Heat release rate/fire growth rate calculations

The heat release rate of a composite fuel is given fundamentally as:

$$\dot{Q} = \sum (\dot{m}_i'' A_i \Delta H_{c,i} \chi_{a,i}) \quad (6)$$

where  $\dot{Q}$  = Total heat release rate of fuel (kW)  
 $\dot{m}_i''$  = Unit mass loss rate of fuel element i (kg/s-m<sup>2</sup>)  
 $A_i$  = Pyrolyzing area of fuel element i (m<sup>2</sup>)  
 $\Delta H_{c,i}$  = Heat of combustion of fuel element i (kJ/kg)  
 $\chi_{a,i}$  = Combustion efficiency factor for fuel element i (-)

The unit mass loss rate of a fuel element is given fundamentally as:

$$\dot{m}_i'' = \frac{\dot{q}_{n,i}''}{L_{g,i}} \quad (7)$$

where  $\dot{q}_{n,i}''$  = Net unit heat flux at the surface of fuel element i (kW/m<sup>2</sup>)  
 $L_{g,i}$  = Effective heat of gasification of fuel element i (kJ/kg)

Consequently, by combining Equations 6 and 7, the heat release rate can be expressed as:

$$\dot{Q} = \sum \left( \dot{q}_{n,i}'' A_i \chi_{a,i} \frac{\Delta H_{c,i}}{L_{g,i}} \right) \quad (8)$$

The term  $\Delta H_c / L_g$  in Equation 8 represents the ratio between the theoretical heat released by combustion of a unit mass of fuel and the heat input required to pyrolyze a unit mass of fuel. This ratio is recognized to be one of the most important parameters relative to the flammability

characteristics of a material. Cleary and Quintiere (1991b) discuss a method to evaluate the terms of this ratio based on Cone Calorimeter test results.

The net heat flux at the fuel surface is composed of a number of flux elements:

$$\dot{q}_n'' = \dot{q}_{ext}'' + \dot{q}_f'' - \dot{q}_r'' - \dot{q}_k'' \quad (9)$$

where  $\dot{q}_{ext}''$  is the external heat flux,  $\dot{q}_f''$  is the flame heat flux,  $\dot{q}_r''$  is the reradiation heat flux from the fuel surface and  $\dot{q}_k''$  is the conductive heat losses from the surface into the fuel. The net heat flux at the fuel surface can be difficult to determine with precision because of the interaction of the flame heat flux with the external heat flux, variations in the reradiative heat flux, particularly for charring materials, and changes in the conductive heat losses with time. As noted by Cleary and Quintiere (1991b), only the external flux is known in the Cone Calorimeter test. Because of these difficulties, predicting heat release rates is difficult, although considerable progress has been made (Quintiere, 1992; Quintiere and Iqbal, 1992). As a consequence, large-scale experiments to measure heat release rates remain necessary to validate predictions based on small-scale tests.

Babrauskas and Krasny (1985b) have developed a simple correlation to predict the peak heat release rate of an article of upholstered furniture base on certain construction features of the article. This method does not predict fire growth rates. Babrauskas and Walton (1986) have developed a triangular approximation to characterize heat release rate curves, while Mowrer and Williamson (1990) have developed power law and exponential characterizations for heat release rate data. These methods are not predictive, but rather provide a means of characterizing measured heat release rate data.

Dietenberger (1988a, 1988b, 1991) has been working on a theoretical model to predict fire growth on upholstered furniture for a number of years. This work illustrates the complexity of the fire growth problem, particularly for three-dimensional objects. Quintiere and a number of his coworkers have been studying fire growth in terms of flame spread processes, principally for wall and ceiling lining applications. These efforts are discussed below in the section on flame spread calculations.

#### 4.1.3 Flame spread calculations

Cleary and Quintiere (1991a) discuss a framework for utilizing fire property test data to describe fire spread over surfaces in wall, floor and ceiling orientations. They have applied this framework to the characterization of the flammability of foam plastics (Cleary and Quintiere, 1991b). Karlsson (1992) has developed a similar, but more complicated, procedure for a specified heat release rate curve shape.

Mowrer and Williamson (1991) apply the general framework of Cleary and Quintiere to the evaluation of the flammability of thin interior finish materials, such as textile wall coverings. Rather than attempt to predict the full heat release rate history, Mowrer and Williamson apply Cone Calorimeter data to a screening procedure that considers limit behavior to predict whether a material is likely to spread a fire in an acceleratory manner or decelerate to extinction for given

exposure conditions. For many applications, this limit behavior may be of more immediate interest than prediction of the complete heat release rate history.

Cleary and Quintiere (1991b) and Mowrer and Williamson (1991) note that the significant flammability parameter for fuels where burnout is significant can be expressed as:

$$FP = k_f \dot{Q}'' - t_f / t_{bo} - 1 \quad (10)$$

where  $k_f$  = Linearized flame length coefficient  
 $\approx 0.01 \text{ m}^2/\text{kW}$   
 $\dot{Q}''$  = Characteristic unit heat release rate ( $\text{kW}/\text{m}^2$ )  
 $t_f$  = Characteristic ignition time, given approximately by Equation 3 above (s)  
 $t_{bo}$  = Fuel burning duration (s)  
 $\approx Q'' / \dot{Q}''$   
 $Q''$  = Characteristic unit energy content of fuel surface ( $\text{kJ}/\text{m}^2$ )

If the flammability parameter given by Equation 10 evaluates to a value greater than zero, then acceleratory flame spread is expected. The higher the value, the more rapid the flame spread to be expected. A flammability parameter less than zero implies deceleration to extinction. The more negative the value, the more likely it is that a flame will not spread significantly on a fuel surface. Slightly negative flammability parameters should be treated with caution because for these circumstances slight perturbations can spell the difference between deceleration to extinction and acceleratory spread.

Evaluation of the terms comprising the flammability parameter requires knowledge of the exposure conditions to which a material is subjected. As shown by Equation 3, higher heat fluxes will cause lower flame spread times and, consequently, higher flammability parameter values. Similarly, significant preheating of a fuel surface will decrease the flame spread time and yield a higher flammability parameter. Higher heat fluxes generally yield higher unit heat release rates, but for a fixed quantity of fuel, higher unit heat release rates will also yield shorter burning durations. These two consequences may tend to offset each other with respect to the effect of higher heat fluxes on the flammability parameter.

The derivation of the flammability parameter is based on a number of assumptions and simplification, so it should be treated as an approximate value. Nonetheless, the flammability parameter expressed by Equation 10 provides a fundamentally sound, semi-quantitative means to evaluate the terms relevant to flame spread. What remains is the development of more definitive means to evaluate the terms that comprise the flammability parameter. Cleary and Quintiere (1991a, 1991b) and Mowrer and Williamson (1991) offer some insight on this topic.

#### 4.1.4 Fire consequence analysis

A large number of fire consequence models have been developed. Friedman (1992) has recently reported on an international survey of computer models for fire and smoke. Most of the computer models reviewed by Friedman can be considered as fire consequence models in that they

calculate fire conditions within an enclosure. For the most part, these models require the user to enter a fire heat release rate as data input. Friedman discusses a number of ways in which a fire may be specified. He also notes that "the input of the burning rate into any computer model of fire is often the most difficult and uncertain element of the model."

## 4.2 Morphological charts of combustibles in buildings

A morphological chart is an enumeration of alternatives for the elements or attributes of an object. For example, Mitchell (1977) presents the following morphological chart for the architectural design of a domestic window:

ELEMENTS	ALTERNATIVES					
FRAME	ALUMINUM	STEEL	WOOD			
GLAZING	SINGLE PANE	DOUBLE PANE				
OPENING SYSTEM	VERTICAL SASH	HORIZONTAL SASH	CASEMENT	PIVOTING	LOUVRE	FIXED GLAZING
PRIVACY SYSTEM	DRAPES	ROLLER BLINDS	REFLECTIVE GLASS			
SUN PROTECTION SYSTEM	VENETIAN BLINDS	EXTERIOR AWNING	SHUTTERS	EXTERIOR LOUVRES	OVERHANGS AND FINS	

Figure 1. Morphological chart of the architectural features of a domestic window.

Mitchell credits Zwicky (1962 and 1967) with popularizing the morphological method approach to engineering design. Zwicky (1967) notes that the morphological method has been used successfully for a comprehensive review of propulsive power plants and propellants (Zwicky, 1962), for the enumeration and analysis of all the processes that can be applied to individual nylon fibers and to enumerate the totality of all possible energy conversions, among other applications.

While a morphological chart such as shown in Figure 1 might be useful for an architect who wants to consider the range of available architectural design options for domestic windows, this particular morphological chart would have limited use for fire safety analysis because other attributes of windows would be more appropriate for fire safety analyses.

The selection of objects and the elements or attributes that compose the objects depends on the anticipated type of analysis. For quantitative building fire hazard analysis, Mowrer and Williamson (1988) have suggested that a building is composed of rooms and that rooms are

composed of boundaries, openings, furnishings and finishes. The room can be considered as the basic object for building fire hazard analyses, and the boundaries, openings, furnishings and finishes as the elements of a room. More recently, Mowrer (1992) has discussed the attributes of different fire safety design elements.

Figure 2 presents a morphological chart of the general types of objects appropriate for building fire hazard analysis. The types of objects shown in Figure 2 differ somewhat from those discussed by Mowrer and Williamson and by Mowrer. The general types of objects shown in Figure 2 are more consistent with the MASTERFORMAT master list of titles and specification numbers for the construction industry developed by the Construction Specifications Institute and Construction Specifications Canada (1988). The MASTERFORMAT system is widely used in the building design and construction industries. It is also used by manufacturers and suppliers to organize and identify their product literature. While MASTERFORMAT is not the only method of organizing the specifications for building products, it seems to be the predominant method in the United States. Use of the MASTERFORMAT system also seems to be growing. It provides a consistent syntax for addressing products used in buildings that can be used by fire safety professionals as well as by other design professionals. For these reasons, it has been used to the extent possible to organize and describe the morphological charts of objects discussed in this document. Numerical references in parentheses in the following morphological charts refer to the appropriate section of the MASTERFORMAT specifications.

ELEMENTS	ALTERNATIVES					
CONSTRUCTION	COLUMNS	BEAMS & GIRDERS	FLOOR-CEILING ASSEMBLY	ROOF-CEILING ASSEMBLY	EXTERIOR WALLS	INTERIOR PARTITIONS
OPENINGS	DOORS	WINDOWS	ROOF VENTS	MECH. VENTS		
FURNISHINGS	FURNITURE	CASEWORK	ARTWORK	WINDOW TREATMENT	STORED COMMODITIES	EQUIPMENT & APPLIANCES

Figure 2. Morphological chart of the major object types for building fire hazard analysis.

Each of these objects is also composed of elements, each with its own multitude of alternatives. Morphological charts for these objects follow. In theory, a morphological chart is an exhaustive enumeration of alternatives. In practice, complete enumeration of all alternatives is not practical because of the wide range of alternative options for each element. Consequently, the morphological charts that follow include generic references to alternatives rather than exhaustive enumerations of alternatives. For example, where an entry of "wood product" is made, it might include a wide range of alternatives from different whole wood species to different processed wood products such as plywood, particle board or flakeboard. Similarly, an entry of "plastic" could be further broken down to enumerate the full range of engineering plastics suitable for a

particular application. While the morphological charts that follow are not complete in this respect, they do provide a syntax for addressing the key elements of the major types of objects in buildings as well as groupings of the types of alternatives available for each type of object. They also provide an indication of just how complex issues of product flammability can be. These morphological charts should be made more comprehensive in the future.

### Columns, Beams and Girders

Columns, beams and girders frequently compose the structural frame of a building, particularly for modern commercial buildings. Structural frame members are commonly insulated to provide a specified level of fire resistance. The surfaces of columns, beams and girders may also be finished, particularly in occupied spaces of buildings, to provide the desired design effect. These features of columns, beams and girders are addressed in the morphological chart shown in Figure 3.

ELEMENTS	ALTERNATIVES				
STRUCTURAL MATERIAL	WOOD	STEEL	CONCRETE	COMPOSITE	
STRUCTURAL SHAPE	BOX	I-BEAM	WIDE FLANGE	BAR JOIST	TRUSS
INSULATION MATERIAL	NONE	CONCRETE/MASONRY	PLASTER	MINERAL FIBERS	GYPSUM BOARD
INSULATION METHOD	NONE	LATH & PLASTER	MEMBRANE	SPRAY APPLIED	ENCASEMENT
FURRING	NONE	WOOD	METAL		
FINISH SUBSTRATE	NONE	GYPSUM BOARD	WOOD PRODUCT		
FINISH FASTENER	NONE	ADHESIVE	MECH. FASTENER		
FINISH	NONE	PAINTED	PAPER	TEXTILE	LAMINATE

Figure 3. Morphological chart for columns, beams and girders.

## Floor/Ceiling Assemblies

Figure 4 shows a morphological chart for floor/ceiling assemblies.

ELEMENTS	ALTERNATIVES						
FLOOR FINISH	NONE	WOOD FLOORING (09550)	STONE FLOORING (09600)	UNIT MASONRY (09630)	RESILIENT FLOORING (09650)	CARPET (09680)	SPECIAL COATINGS (07570 & 09800)
PADDING	NONE	HAIR/JUTE (09682)	REBOND PU FOAM (09682)	NEW PU FOAM (09682)			
FASTENER	NONE	ADHESIVE (09680)	MECH. FASTENER (06050)				
FLOOR SHEATHING	WOOD DECKING (06125)	TIMBER DECKING (06140)	METAL DECKING (05300)	CEMENT. DECK (03500)			
STRUCTURAL SUPPORT	WOOD FRAMING (06110)	HEAVY TIMBER (06130)	WOOD & METAL (06150)	PREFAB. WOOD (06170)	CONCRETE (DIV. 3)	METAL FRAMING (05100)	METAL JOISTS (05200)
CEILING SUPPORT SYSTEM	NONE	FURRING & LATHING (09205)	METAL SUPPORT (09100)	MECH. FASTENER (06050)			
CEILING SHEATHING	NONE	GYPSUM BOARD (09250)	WOOD PRODUCT (09545)	SPECIAL SURFACES (09545)			
FASTENER	NONE	ADHESIVE (09680)	MECH. FASTENER (06050)				
CEILING FINISH	NONE	PAINTED (09900)	PAPER (09950)	TEXTILE (09680)	LAMINATE (06240)	ACOUSTICAL TILE OR PANEL (09510)	

Figure 4. Morphological chart for floor/ceiling assemblies.

The floor part of a floor/ceiling assembly can consist of a number of layers of materials, all of which may influence the flammability of the floor finish. For example, research at NBS in the 1970s on the flammability of floor coverings demonstrated that the presence of a carpet pad influences the flammability performance of floor coverings. In a similar way, the details of the ceiling construction will influence the flammability of the ceiling. The details for a test assembly should match the details of a field assembly to the extent possible. Any discrepancies should be evaluated in terms of their potential effect on flammability.

## Roof/Ceiling Assemblies

Figure 5 shows a morphological chart for roof/ceiling assemblies.

ELEMENTS	ALTERNATIVES							
ROOFING TYPE	SHINGLES & TILES (07300)	MEMBRANE (07500)	MANU-FACTURED (07400)					
ROOFING MATERIAL	ASPHALT SHINGLES (07310)	WOOD SHAKES (07310)	CLAY TILES (07320)	SLATE SHINGLES (07310)	METAL PANELS (07410)	BUILT-UP ASPHALT (07510)	SINGLE-PLY MEMBRANE (07530)	
FASTENER	NONE	ADHESIVE (09680)	MECH. FASTENER (06050)					
ROOF INSULATION TYPE	NONE	BOARD-STOCK (07220)	BATTS (07210)	SPRAYED (07210)	LOOSE-FILL (07210)			
ROOF INSULATION MATERIAL	NONE	FIBER-GLASS	POLY-STYRENE	POLY-URETHANE	CELLULOSIC			
VAPOR RETARDER	NONE	KRAFT PAPER	POLY-ETHYLENE FILM	PVC FILM				
ROOF SHEATHING	WOOD DECKING (06125)	TIMBER DECKING (06140)	METAL DECKING (05300)	CEMENT. DECKS (03500)				
STRUCTURAL SUPPORT	WOOD FRAMING (06110)	HEAVY TIMBER (06130)	WOOD & METAL (06150)	PREFAB. WOOD (06170)	CONCRETE (DIV. 3)	METAL FRAMING (05100)	METAL JOISTS (05200)	
CEILING SUPPORT SYSTEM	NONE	FURRING & LATHING (09205)	METAL SUPPORT (09100)	MECH. FASTENER (06050)				
CEILING SHEATHING	NONE	GYPSUM BOARD (09250)	WOOD PRODUCT (09545)	SPECIAL SURFACES (09545)				
FASTENER	NONE	ADHESIVE (09680)	MECH. FASTENER (06050)					
CEILING FINISH	NONE	PAINTED (09900)	PAPER (09950)	TEXTILE (09680)	LAMINATE (06240)	ACOUSTICAL TILE OR PANEL (09510)		

Figure 5. Morphological chart for roof/ceiling assemblies.

Traditionally, the inside and outside surfaces of roof/ceiling assemblies have been considered separately with respect to fire safety issue. The exterior roof surface may be subjected to an external fire, either by direct flame impingement or by flying fire brands. A standard fire test is used to address these exposure conditions. The ceiling finish is exposed to the occupied space and is regulated by interior finish provisions in building codes.

## Interior Partitions

Figure 6 shows a morphological chart for interior partitions.

ELEMENTS	ALTERNATIVES						
INTERIOR WALL FINISH	NONE	PAINTED (09900)	PAPER (09950)	TEXTILE (09680)	LAMINATE (06240)		
FASTENER	NONE	ADHESIVE (06050)	MECH. FASTENER (06050)				
INTERIOR SUBSTRATE	NONE	GYPSUM BOARD (09250)	LATH & PLASTER (09200)	WOOD PRODUCT (09545)	SPECIAL SURFACES (09540)		
FASTENER	NONE	ADHESIVE (06050)	MECH. FASTENER (06050)				
STRUCTURAL SUPPORT	WOOD FRAMING (06110)	HEAVY TIMBER (06130)	WOOD & METAL (06150)	PREFAB. WOOD (06170)	CONCRETE (DIV. 3)	METAL FRAMING (DIV. 5)	MASONRY (04200)
FASTENER	NONE	ADHESIVE (06050)	MECH. FASTENER (06050)				
INTERIOR SUBSTRATE	NONE	GYPSUM BOARD (09250)	LATH & PLASTER (09200)	WOOD PRODUCT (09545)	SPECIAL SURFACES (09540)		
FASTENER	NONE	ADHESIVE (06050)	MECH. FASTENER (06050)				
INTERIOR WALL FINISH	NONE	PAINTED (09900)	PAPER (09950)	TEXTILE (09680)	LAMINATE (06240)		

Figure 6. Morphological chart for interior partitions.

The surface area of interior partitions is usually a major fraction of the total surface area of the boundaries of a space. Along with ceilings, walls represent the best avenue for surface flame spread on interior finishes. Consequently, the flammability of the interior finish of walls and ceilings has been regulated by building codes for many years. Figure 6 identifies some of the construction details that should be included in the consideration of the flammability of such finish assemblies.

## Exterior Walls

Figure 7 shows a morphological chart for exterior walls.

ELEMENTS	ALTERNATIVES									
EXTERIOR SIDING	NONE	ALUMINUM & STEEL (07460)	COMPOSITION (07460)	HARD-BOARD (07460)	WOOD & PLYWOOD (07460)	MANUFACTURED (07410)	MASONRY (04200)	STUCCO (09200)	PLASTIC (07460)	
FASTENER	NONE	ADHESIVE (09680)	MECH. FASTENER (06050)							
EXTERIOR SHEATHING	NONE	WOOD & PLYWOOD (06100)	GYPSUM BOARD (09250)	INSULATING BOARD (07200)						
FASTENER	NONE	ADHESIVE (09680)	MECH. FASTENER (06050)							
WALL INSULATION TYPE	NONE	BOARD-STOCK (07220)	BATTS (07210)	SPRAYED (07210)	LOOSE-FILL (07210)	EXTERIOR SYSTEM (07240)				
WALL INSULATION MATERIAL	NONE	FIBER-GLASS	POLY-STYRENE	POLY-URETHANE	CELLULOSIC					
VAPOR RETARDER	NONE	KRAFT PAPER	POLY-ETHYLENE FILM	PVC FILM						
STRUCTURAL SUPPORT	WOOD FRAMING (06110)	HEAVY TIMBER (06130)	WOOD & METAL (06150)	PREFAB. WOOD (06170)	CONCRETE (DIV. 3)	METAL FRAMING (DIV. 5)	MASONRY (04200)			
FASTENER	NONE	ADHESIVE (06050)	MECH. FASTENER (06050)							
INTERIOR SUBSTRATE	NONE	GYPSUM BOARD (09250)	LATH & PLASTER (09200)	WOOD PRODUCT (09545)	SPECIAL SURFACES (09540)					
FASTENER	NONE	ADHESIVE (06050)	MECH. FASTENER (06050)							
INTERIOR WALL FINISH	NONE	PAINTED (09900)	PAPER (09950)	TEXTILE (09680)	LAMINATE (06240)					

Figure 7. Morphological chart for exterior walls.

Exterior walls are different from interior partitions because they typically include elements for weather protection as well as for thermal insulation on the exterior side. The interior side of exterior walls typically will have the same elements as the two faces of an interior partition.

## Windows

Figure 8 shows a morphological chart for windows.

ELEMENTS	ALTERNATIVES					
WINDOW TYPE	FIXED	VERTICAL SASH	HORIZ. SASH	CASEMENT	PIVOTING	LOUVRE
FRAME	NONE	WOOD (08610)	PLASTIC (08630)	STEEL (08510)	ALUMINUM (08520)	
GLAZING MATERIAL (08800)	ANNEALED GLASS (08810)	LAMINATED GLASS (08810)	TEMPERED GLASS (08810)	WIRED GLASS (08810)	PMMA (08840)	POLY-CARBONATE (08840)
GLAZING TYPE	SINGLE PANE	DOUBLE PANE	TRIPLE PANE			
GLAZING METHOD	GLAZING POINTS & PUTTY	GLAZING CLIPS	NEOPRENE GASKETS	SILICONE CAULK		
WINDOW TREATMENT (12500)	NONE	BLINDS (12510)	SHADES (12520)	CURTAINS (12540)	SOLAR CONTROL FILM (12525)	INTERIOR SHUTTERS (12515)

Figure 8. Morphological chart for windows.

Windows are important from the standpoint of fire hazard analysis because they can act as vents, depending on whether they are open or closed at the time of a fire. In many fires, windows break due to thermally-induced stresses. Considerable research has been conducted in recent years on the failure mechanisms of window glass. This research suggests that windows commonly break when the edges of the glass are shielded from incident heat by a window frame while the glazing is exposed to the incident heat. The heated glass wants to expand while the cool glass does not. This induces the stresses that ultimately can lead to failure.

As evidenced by the range of possible window configurations enumerated in Figure 8, research on glass breakage in fire has only scratched the surface of this issue.

## Doors

Doors come in a variety of types to serve a variety of functions. Doors typically represent only a small fraction of the surface area of a room, so the flammability of doors is not often raised as an important issue in fire hazard analyses, despite the fact that some facing veneers and foam plastic core materials are relatively flammable. More frequently, doors are considered in the context of their service as fire and smoke barriers. Most of the elements shown in Figure 9, the morphological chart for doors, relate to the performance of doors as fire barriers.

ELEMENTS	ALTERNATIVES					
DOOR TYPE	SWINGING (08100 & 08200)	REVOLVING (08400)	SLIDING (08310)	SECTIONAL OVERHEAD (08360)	COILING OVERHEAD (08330)	FOLDING (08350)
DOOR CONST. MATERIAL	WOOD (08200)	METAL (08100)	GLASS (08300 & 08400)			
CORE TYPE	NONE	HOLLOW	SOLID	FOAM		
CORE MATERIAL	NONE	WOOD	KALAMEIN	POLY- URETHANE	POLY- STYRENE	
FACING/ VENEER	NONE	WOOD	METAL	PLASTIC LAMINATE		
GLAZING TYPE	NONE	VISION PANEL	TOP PANEL	TOP & BOTTOM PANEL		
GLAZING MATERIAL	NONE	WIRED GLASS	TEMPERED GLASS	ANNEALED GLASS	PLASTIC	
LATCHING HARDWARE	NONE	PANIC HARDWARE	DOORKNOB	DEADBOLT		
CONTROL HARDWARE	NONE	SELF- CLOSING	AUTO- CLOSING			
DOOR FRAME	WOOD	METAL				

Figure 9. Morphological chart for doors.

## Furniture

Figure 10 shows a morphological chart for furniture intended for seating. This includes chairs, loveseats and sofas. A separate morphological chart for beds is shown in Figure 11. These represent the two broad categories of furniture intended to support people in a seated or reclined position. Other furniture, such as desks and bookshelves, intended to act as work surfaces or storage containers are considered as casework, described in the section below.

The elements selected for the morphological chart in Figure 10 are based on the elements suggested by Babrauskas and Krasny (1985a, 1985b) as influencing the burning rate of upholstered furniture articles.

ELEMENTS	ALTERNATIVES						
FABRIC	NONE	COTTON/ LINEN/ RAYON	NYLON/ OLEFIN	PVC	WOOL	BLEND	
INTERLINER/ BATTING	NONE	COTTON	POLY- ESTER	NEOPRENE/ VONAR	FIBER- GLASS	ALUMINIZED FABRICS	
PADDING	NONE	PU FOAM (NFR & FR)	COTTON (NFR & FR)	CMHR/ MELAMINE PU FOAMS	NEOPRENE	PS BEADS	LATEX FOAM
FRAME	NONE	WOOD PRODUCT	METAL/ NONCOM- BUSTIBLE	MOLDED THERMO- PLASTIC	STRUCT. FOAM (CHARRING)		
STYLE	RECTI- LINEAR	CONVO- LUTED					

Figure 10. Morphological chart for seating furniture.

The standard sizes and plane surfaces of beds belie the variety of factors that influence how beds burn. The elements of beds that may influence their burning behavior are identified in Figure 11.

ELEMENTS	ALTERNATIVES							
COVERS	NONE	COTTON/ LINEN/ RAYON	NYLON/ OLEFIN	POLYESTER	WOOL	DOWN/ FEATHERS	BLEND	
SHEETS/ LINENS	NONE	COTTON/ LINEN	COTTON/ POLYESTER					
MATTRESS COVER	NONE	COTTON	COTTON/ POLYESTER	VINYL				
DECUBIDUS PAD	NONE	PU FOAM (NFR & FR)	COTTON (NFR & FR)	NEOPRENE				
TICKING	NONE	COTTON	COTTON/ POLYESTER	VINYL				
INTERLINER/ BATTING	NONE	COTTON	POLY- ESTER	NEOPRENE/ VONAR	FIBER- GLASS	ALUMINIZED FABRICS		
PADDING	NONE	PU FOAM (NFR & FR)	COTTON (NFR & FR)	CMHR/ MELAMINE PU FOAMS	LATEX FOAM	NEOPRENE	FEATHERS	
MATTRESS STYLE	SOLID PAD	INNER- SPRING						
MATTRESS SUPPORT BASE	NONE	FOUN- DATION	BOX SPRING					
BED FRAME	NONE	WOOD	METAL/ NONCOM- BUSTIBLE					
HEADBOARD/ BASEBOARD	NONE	WOOD	METAL/ NONCOM- BUSTIBLE					
DUST RUFFLE	NONE	COTTON	COTTON/ POLYESTER	POLY- ESTER				

Figure 11. Morphological chart for beds.

Figure 11. Morphological chart for beds.

## Casework

Casework includes the cabinets, bookcases, shelves, desks and other furniture used for storage or work surfaces. Casework may be manufactured at a factory and purchased as a product or it may be custom installed by skilled carpenters. In either case, the elements of casework can be identified. Figure 12 shows a morphological chart for casework.

ELEMENTS	ALTERNATIVES					
TYPE	CUSTOM (06200 & 06410)	MANUFACTURED (12300)				
FRAME	WOOD	PLASTIC	METAL			
SIDE FINISH	OPEN	WOOD PRODUCT	METAL	PLASTIC LAMINATE		
BACK FINISH	OPEN	WOOD PRODUCT	METAL	PLASTIC LAMINATE		
WORK SURFACE SUBSTRATE	NONE	PLYWOOD	PARTICLE BOARD	MORTAR BOARD	METAL	
WORK SURFACE FINISH	NONE	WOOD VENEER	PLASTIC LAMINATE	CERAMIC TILE	SYNTHETIC MARBLE	GRANITE
DOORS	NONE	WOOD PRODUCT	METAL	PLASTIC LAMINATE	STRUCT. FOAM	
SHELVES	NONE	WOOD PRODUCT	METAL	PLASTIC LAMINATE		
DRAWER CONST.	NONE	WOOD PRODUCT	METAL	PLASTIC LAMINATE		
DRAWER FRONTS	NONE	WOOD PRODUCT	METAL	PLASTIC LAMINATE		

Figure 12. Morphological chart for casework.

## Artwork

Artwork includes murals, sculpture and wall decorations, such as paintings, tapestries and wall hangings. Artwork is addressed in Section 12100 of MASTERFORMAT. A morphological chart for artwork is shown in Figure 13.

ELEMENTS	ALTERNATIVES					
TYPE	MURAL (12110)	WALL DEC- ORATION (12120)	SCULP- TURE (12140)			
FRAME	NONE	WOOD	PLASTIC	METAL		
GLAZING	NONE	GLASS	PLASTIC			
SURFACE FINISH	NONE	PAINTED	FABRIC	METAL	WOOD PRODUCT	PLASTIC
SUBSTRATE	NONE	CANVAS	WOOD PRODUCT	PLASTIC	METAL	

Figure 13. Morphological chart for artwork.

## Window Treatment

Window treatment is addressed in Section 12500 of MASTERFORMAT. Window treatment is included in Figure 8, the morphological chart for windows. A more detailed treatment is provided in Figure 14.

ELEMENTS	ALTERNATIVES						
EXTERIOR PROTECTION	NONE	LOUVER	BLINDS	SUN-SCREEN	SHUTTERS	AWNING	
SOLAR CONTROL FILM	NONE	BRONZE	MIRROR)	LOW E	ALUMINUM (08520)		
BLIND TYPE	NONE	HORI-ZONTAL	VERTICAL				
BLIND MATERIAL	NONE	METAL	WOOD	PLASTIC			
CURTAIN TYPE	NONE	SHEERS	DRAPERIES	WOVEN WOOD	VERTICAL LOUVER		
CURTAIN MATERIAL	NONE	COTTON	POLY-ESTER	BLEND	FIBER-GLASS	WOOD	VINYL
CURTAIN LINER	NONE	COTTON	POLY-ESTER	BLEND	FIBER-GLASS	WOOD	VINYL
CURTAIN HARDWARE	NONE	THERMO-PLASTIC EYES	METAL EYES				

Figure 14. Morphological chart for window treatments.

## Stored Commodities

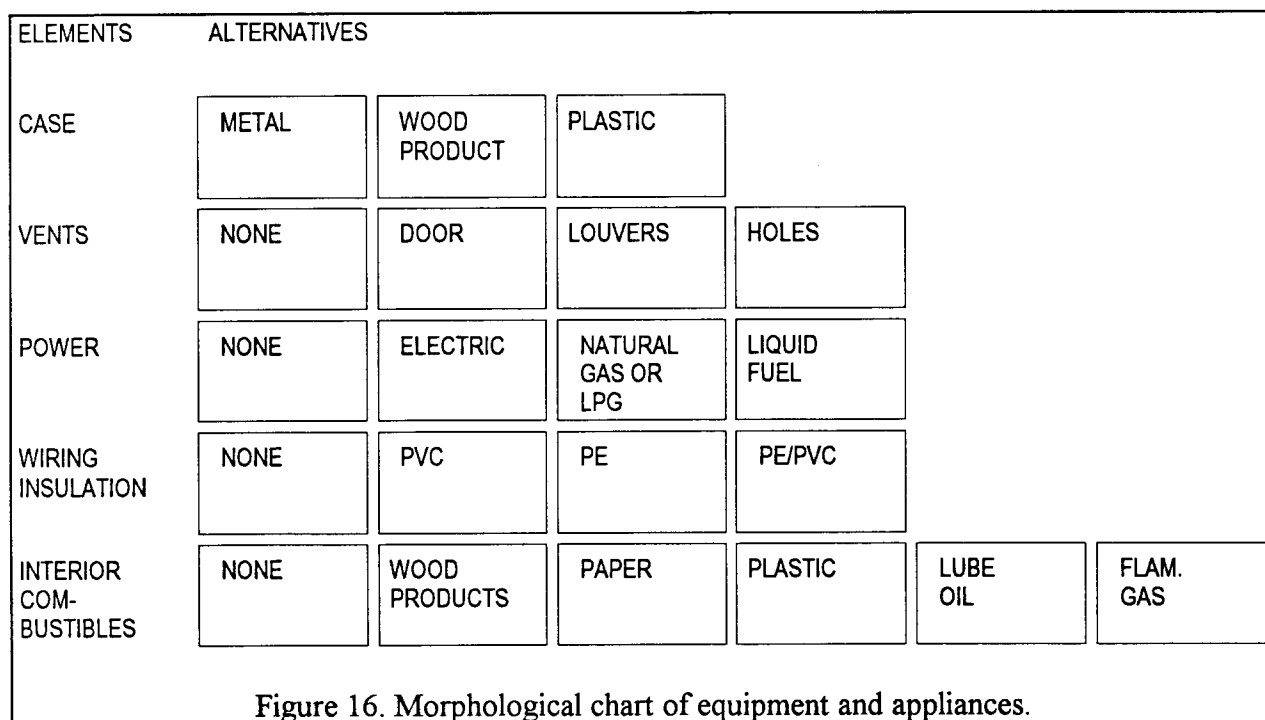
Stored commodities range from a few books stacked on a desk to a warehouse filled with many different products in packages and shipping containers stored in racks. Nonetheless, it is possible to begin to classify the range of storage arrangements in terms of a number of key elements and alternatives. The classification system used here is used by NFPA in some of its automatic sprinkler design standards, including NFPA 231 and 231C. While not comprehensive, this classification system can serve as the starting point in the construction of a more complete morphological chart for stored commodities. A morphological chart for stored commodities is shown in Figure 15.

ELEMENTS	ALTERNATIVES									
COMMODITY CLASS	NONCOM-BUSTIBLE	CLASS I	CLASS II	CLASS III	CLASS IV	GROUP A PLASTIC	GROUP B PLASTIC	GROUP C PLASTIC	FLAM. & COMB. LIQUIDS	
CONTAINER	NONE	CARD-BOARD	WOOD PRODUCT	METAL						
PACKAGING MATERIAL	NONE	PAPER	CARD-BOARD	PLASTIC FILM	FOAM PLASTIC	METAL				
STORAGE ARRANGEMENT	UNIT LOAD	CARTONED	EXPOSED	ENCAP-SULATED						
STORAGE TYPE	SHELF	RACK	BIN BOX	SOLID PILE						
STORAGE STABILITY	STABLE	UNSTABLE								

Figure 15. Morphological chart for stored commodities.

## Equipment and Appliances

Equipment and appliances include both general building service equipment common to most buildings, such as heating and cooling plants and conveyor systems, to devices particular to a very specialized application, such as an X-ray machine in a health care facility or an athletic mat in a gymnasium. In the MASTERFORMAT system, Division 11 is devoted to equipment of many different types, while Divisions 14 through 16 cover conveying systems, mechanical systems and electrical systems, respectively. Because of the range of types of equipment and appliances, it is difficult to construct a single morphological chart to cover the full range. Nonetheless, from the standpoint of flammability, it is possible to address common elements and alternatives for equipment and appliances. Such a morphological chart is shown in Figure 16. This morphological chart is not exhaustive, but it does address many of the key characteristics that distinguish the flammability characteristics of most equipment and appliances.



## 5.0 SUMMARY AND CONCLUDING REMARKS

The Fire Data Management System is intended to permit consolidation of fire test data from laboratories around the world. One goal of the FDMS is to permit the convenient transfer of fire test results between laboratories in a standardized format. Another goal is to make the FDMS useful for and available to practicing fire safety professionals. This project has been directed towards this second goal.

The current data structure of the FDMS is of limited utility to practicing fire safety professionals. It is too difficult to extract data for a particular product or application because products are identified in only two product ID data fields. This is inadequate for most realistic combustible products in buildings, particularly for composite materials, many of which include a finish material, an adhesive and a substrate material, at a minimum. It is recommended that the data structure of the FDMS be expanded so the context of use is included for data stored in the FDMS. This would permit practicing fire safety professionals to access the data based on the use rather than the type of materials. Materials with more than one use could be associated with each of their uses.

A number of morphological charts of combustibles in buildings have been developed. The first of these, shown in Figure 2, identifies the general types of combustibles used in buildings. Subsequent morphological charts identify the elements and alternatives of the different types of combustibles in buildings. These morphological charts represent a first effort to identify and

perhaps codify a syntax for the range of combustibles in buildings as well as their physical makeup. Further refinement of these morphological charts is needed.

The morphological charts are not comprehensive at present and it will not be practical to make them completely so. For example, where a box in a morphological chart identifies "plastic" or "wood product" as an alternative, that box could be replaced with a myriad of choices of different plastic or wood-based products. It should be quite apparent that the range of possible combinations is enormous. Consequently, it will be desirable to group and classify alternatives to the extent possible. If the burning characteristics of different materials are similar, then they could be grouped together. For example, many wood-based materials may exhibit similar burning behavior. Similarly, differences in the performance of thermoplastic fabrics used in upholstered furniture may not be large, in which case these fabrics could all be grouped together. Babrauskas and Krasny (1985a, 1985b) have attempted to develop such a classification scheme for upholstered furniture. Similar efforts should be undertaken for other design elements.

Data from a large number of fire tests have been acquired at the BFRL at NIST as well as at other fire laboratories internationally. Some of these data have been converted to the FDMS format. Conversion of additional data should await revision of the FDMS data structure to accommodate data fields that identify the context of use. Compared with the range of possible combinations of materials identified in the morphological charts developed here, however, the data set is sparse. A concerted effort will be needed to fill out the data set and to revise the data structure of the FDMS to make it more useful to practicing fire safety professionals. Further work on grouping and classifying alternatives would aid this process considerably. Additional work is also needed on the development of models that use bench-scale fire test data to predict large-scale performance.

## 6.0 REFERENCES

- Babrauskas, V., and Krasny, J.F., 1985a, "Fire Behavior of Upholstered Furniture," *NBS Monograph 173*, National Bureau of Standards, Gaithersburg, MD.
- Babrauskas, V., and Krasny, J.F., 1985b, "Prediction of Upholstered Chair Heat Release Rates from Bench-Scale Measurements," *Fire Safety: Science and Engineering, ASTM STP 882*, T.Z. Harmathy (Ed.), American Society for Testing and Materials, Philadelphia, PA, pp. 268-284.
- Babrauskas, V., and Walton, W.D., 1986, "A Simplified Characterization for Upholstered Furniture Heat Release Rates," *Fire Safety Journal*, 11, pp. 181-192.
- Belles, D.W., Fisher, F.L., and Williamson, R.B., 1988, "How Well Does ASTM E-84 Predict Fire Performance of Textile Wallcoverings?," *Fire Journal*, 82 (1), pp. 24-30, 74.
- Belles, D. W., and Beitel, J.J., 1988, "Do Multi-Layer Draperies Pass the Single-Layer Fire Tests?," *Fire Journal*, 82 (5), pp. 25-30, 91.

Cleary, T.G., and Quintiere, J.G., 1991a, "A Framework for Utilizing Fire Property Tests," *NISTIR 4619*, National Institute of Standards and Technology, Gaithersburg, MD.

Cleary, T.G., and Quintiere, J.G., 1991b, "Flammability Characterization of Foam Plastics," *NISTIR 4664*, National Institute of Standards and Technology, Gaithersburg, MD.

Construction Specifications Institute, 1988, *MASTERFORMAT - Master List of Titles and Numbers for the Construction Industry*, Alexandria, VA.

Dietenberber, M.A., 1988a, "Improved Furniture Fire Model Within 'FAST': HEMFAST-2," *NBS-GCR-88-545*, National Bureau of Standards, Gaithersburg, MD.

Dietenberber, M.A., 1988b, "A Validated Furniture Fire Model with FAST (HEMFAST)," *NIST-GCR-89-564*, National Institute of Standards and Technology, Gaithersburg, MD.

Dietenberber, M.A., 1992, "Modifications to Furniture Fire Model for HAZARD System," *NIST-GCR-92-601*, National Institute of Standards and Technology, Gaithersburg, MD.

DiNenno, P.J.(Ed.-in-Chief), 1988, *SFPE Handbook of Fire Protection Engineering*, National Fire Protection Association, Quincy, MA.

Friedman, R., 1992, "An International Survey of Computer Models for Fire and Smoke," *Journal of Fire Protection Engineering*, 4 (3), pp. 81-92.

Mitchell, W., 1977, *Computer-Aided Architectural Design*, Van Nostrand Reinhold Company, New York, p. 34.

Mowrer, F. W., and Williamson, R.B., 1988, "Room Fire Modeling Within a Computer-Aided Design Framework," *Fire Safety Science - Proceedings of the Second International Symposium*, Hemisphere Publishing Corporation, New York, pp. 453-462.

Mowrer, F. W., and Williamson, R.B., 1990, "Methods to Characterize Heat Release Rate Data," *Fire Safety Journal*.

Mowrer, F.W., 1992, "Integration of Fire Models with the Design Process," *Fire Protection Handbook (17th ed.)*, A.E. Cote (Ed.-in-Chief), National Fire Protection Association, Quincy, MA, pp. 10-113 - 10-123.

Peacock, R.D., Forney, G.P., Reneke, P., Portier, R., and Jones, W.W., "CFAST, the Consolidated Model of Fire Growth and Smoke Transport," *NIST Technical Note 1299*, National Institute of Standards and Technology, Gaithersburg, MD.

Poitier, R.W., 1993, "A Programmer's Reference Guide to FDMS File Formats," *NISTIR 5162*, National Institute of Standards and Technology, Gaithersburg, MD.

Quintiere, J.G., 1992, "A Semi-Quantitative Model for the Burning Rate of Solid Materials," *NISTIR 4840*, National Institute of Standards and Technology, Gaithersburg, MD.

Quintiere, J. and Iqbal, N., 1992, "A Burning Rate Model for Materials," Department of Fire Protection Engineering, University of Maryland, College Park, MD.

Zwicky, F., 1962, *Morphology of Propulsive Power*, Society for Morphological Research, Pasadena, CA.

Zwicky, F., 1967, "The Morphological Approach to Discovery, Invention, Research and Construction," *New Methods of Thought and Procedure*, F. Zwicky and A.G. Wilson (Eds.), Springer-Verlag, New York.

NIST-114 (REV. 6-93) ADMAN 4.09	<b>U.S. DEPARTMENT OF COMMERCE</b> <b>NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY</b>	<b>(ERB USE ONLY)</b>	
<h2 style="margin: 0;">MANUSCRIPT REVIEW AND APPROVAL</h2>		ERB CONTROL NUMBER	DIVISION
		PUBLICATION REPORT NUMBER NIST-GCR-94-639	CATEGORY CODE
INSTRUCTIONS: ATTACH ORIGINAL OF THIS FORM TO ONE (1) COPY OF MANUSCRIPT AND SEND TO THE SECRETARY, APPROPRIATE EDITORIAL REVIEW BOARD.		PUBLICATION DATE June 1994	NUMBER PRINTED PAGE
TITLE AND SUBTITLE (CITE IN FULL)  Development of the Fire Data Management System			
CONTRACT OR GRANT NUMBER 60NANB1D1164		TYPE OF REPORT AND/OR PERIOD COVERED Final Report	
AUTHOR(S) (LAST NAME, FIRST INITIAL, SECOND INITIAL) Frederick W. Mowrer University of Maryland College Park, MD 20742		PERFORMING ORGANIZATION (CHECK (X) ONE BOX) <input type="checkbox"/> NIST/GAITHERSBURG <input type="checkbox"/> NIST/BOULDER <input checked="" type="checkbox"/> JILA/BOULDER	
LABORATORY AND DIVISION NAMES (FIRST NIST AUTHOR ONLY)			
SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP) U.S. Department of Commerce National Institute of Standards and Technology Gaithersburg, MD 20899			
PROPOSED FOR NIST PUBLICATION			
<input type="checkbox"/> JOURNAL OF RESEARCH (NIST JRES) <input type="checkbox"/> J. PHYS. & CHEM. REF. DATA (JPCRD) <input type="checkbox"/> HANDBOOK (NIST HB) <input type="checkbox"/> SPECIAL PUBLICATION (NIST SP) <input type="checkbox"/> TECHNICAL NOTE (NIST TN)	<input type="checkbox"/> MONOGRAPH (NIST MN) <input type="checkbox"/> NATL. STD. REF. DATA SERIES (NIST NSRDS) <input type="checkbox"/> FEDERAL INF. PROCESS. STDS. (NIST FIPS) <input type="checkbox"/> LIST OF PUBLICATIONS (NIST LP) <input type="checkbox"/> NIST INTERAGENCY/INTERNAL REPORT (NISTIR)	<input type="checkbox"/> LETTER CIRCULAR <input type="checkbox"/> BUILDING SCIENCE SERIES <input type="checkbox"/> PRODUCT STANDARDS <input checked="" type="checkbox"/> OTHER <u>NIST-GCR</u>	
PROPOSED FOR NON-NIST PUBLICATION (CITE FULLY)		<input type="checkbox"/> U.S. <input type="checkbox"/> FOREIGN	PUBLISHING MEDIUM <input checked="" type="checkbox"/> PAPER <input type="checkbox"/> CD-ROM <input type="checkbox"/> DISKETTE (SPECIFY) _____ <input type="checkbox"/> OTHER (SPECIFY) _____
ABSTRACT (A 2000-CHARACTER OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, CITE IT HERE. SPELL OUT ACRONYMS ON FIRST REFERENCE.) (CONTINUE ON SEPARATE PAGE, IF NECESSARY.)  <p>The Fire Data Management System (FDMS) is being developed under international collaboration to provide uniform means for storing fire test data. The purpose of the present work has been to aid the development of the FDMS for practical use by fire safety design professionals with respect to the following three tasks:</p> <ul style="list-style-type: none"> <li>Recovery of existing data at BFRL/NIST for implementation into the FDMS.</li> <li>Generation of additional data not already available.</li> <li>Development of engineering guidelines for use of the FDMS.</li> </ul> <p>To be of practical use by fire safety design professionals, the FDMS must contain relevant data and these data must be readily accessible. Currently, the data fields in the FDMS are too general and too restricted to be of practical design use. Additional data fields are needed in the FDMS to assist the design professional find flammability test data relevant to the design of different combustible objects in buildings. To help identify the types of additional data fields that are needed, a series of morphological charts have been developed to describe the types, elements and attributes of combustible objects in buildings. These morphological charts represent a first effort to describe a common syntax for identifying appropriate objects and their attributes for flammability analyses. Further refinement of the charts is needed.</p>			
KEY WORDS (MAXIMUM OF 9; 28 CHARACTERS AND SPACES EACH; SEPARATE WITH SEMICOLONS; ALPHABETIC ORDER; CAPITALIZE ONLY PROPER NAMES) cone calorimeters; corner tests; databases; fire safety; flame spread; furniture calorimeters; heat release; numeric databases; room tests; small scale fire tests			
AVAILABILITY <input checked="" type="checkbox"/> UNLIMITED <input type="checkbox"/> FOR OFFICIAL DISTRIBUTION - DO NOT RELEASE TO NTIS <input type="checkbox"/> ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GPO, WASHINGTON, DC 20402 <input checked="" type="checkbox"/> ORDER FROM NTIS, SPRINGFIELD, VA 22161		NOTE TO AUTHOR(S): IF YOU DO NOT WISH THIS MANUSCRIPT ANNOUNCED BEFORE PUBLICATION, PLEASE CHECK HERE. <input type="checkbox"/>	